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(54) Control in response to eye closure for the handicapped

(57) To produce a control signal in response to closure of the eye, a visible light transmitter 15 and receiver 16 are mounted on a spectacle frame or similar so as to be

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ERRATA

SPECIFICATION NO 2075671 A

Front page, heading (57) Abstract
line 12, after *The insert* relatively directional characteristics of the

line 12, after *eye insert* normally

line 13, after *little insert radiated after light insert back to the receiver*

line 14, after *eyelid insert allows a relatively greater amount of radiated light to be received for eye read eyelid*

Page 3, line 76, for received read received

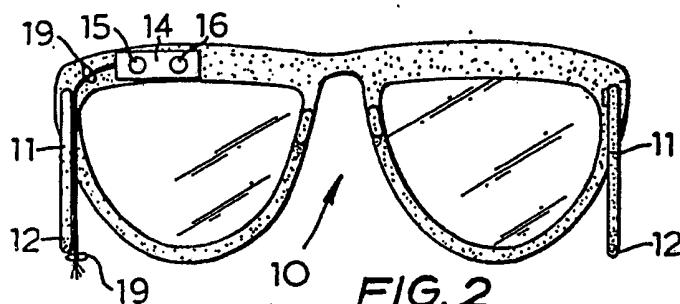
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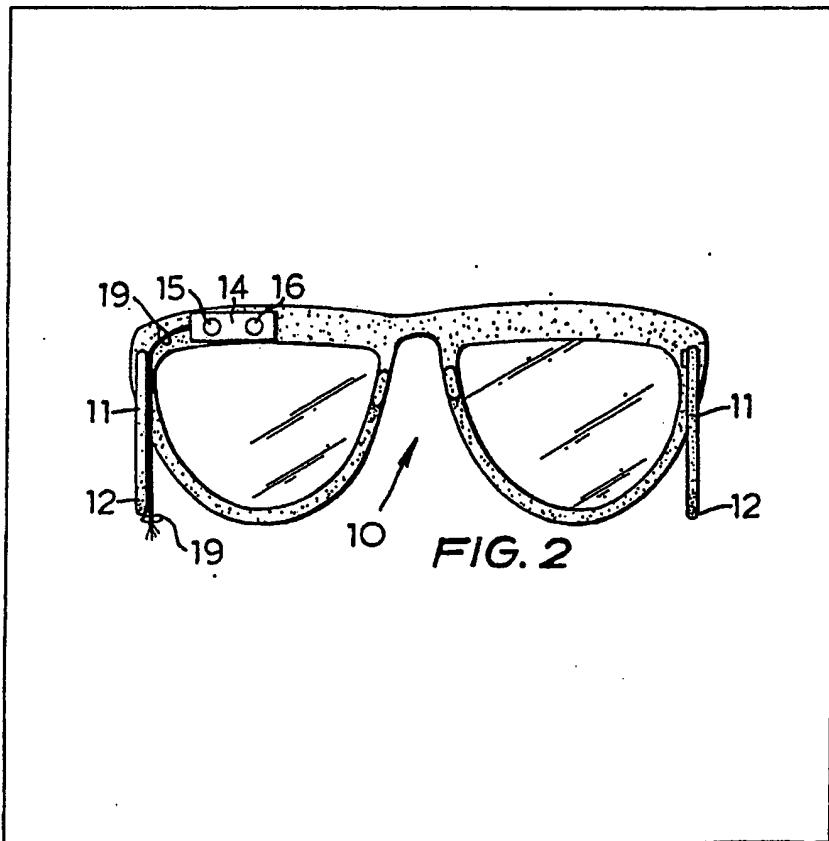
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(54) Control in response to eye closure for the handicapped

(57) To produce a control signal in response to closure of the eye, a visible light transmitter 15 and receiver 16 are mounted on a spectacle frame or similar so as to be situated above and in front of the eye. Conductors 19 are connected to a control circuit arranged to supply modulated current to the transmitter 15 and to respond to changes in light levels received by the receiver 16. The open eye reflects little light, but the scattering effect of the eyelid when the eye is closed reflects a greater amount of light to the receiver 16. Comparing the phase of the transmitted and received light allows effects of ambient light to be eliminated, and a delay circuit discriminates deliberate eye closure from blinking. A com-

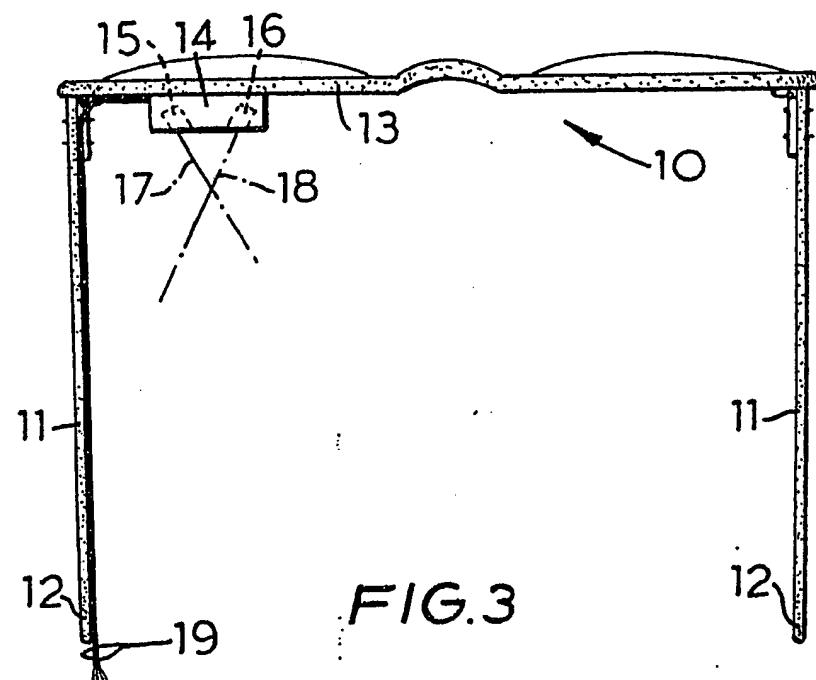
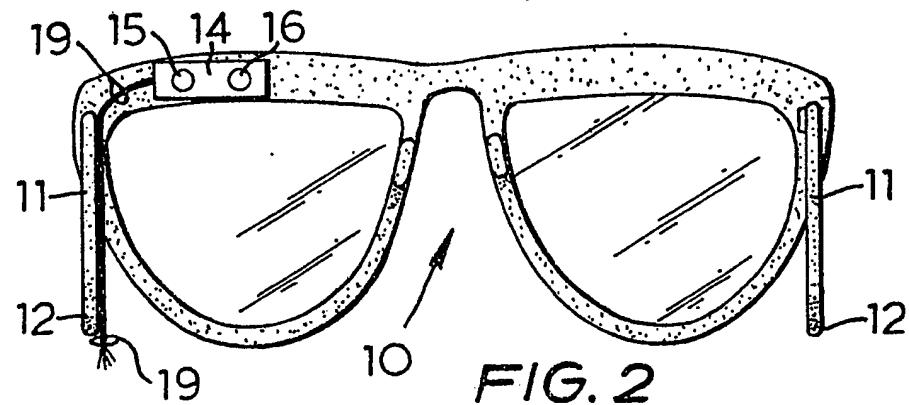
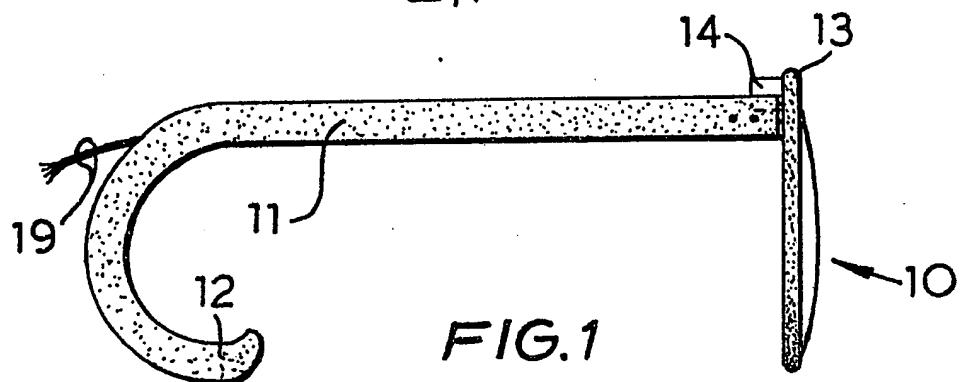
puter may display a sequence of characters on a visual display unit and respond to the control signal so as to store for further processing e.g. printing the character being displayed at the time. The control signal may control other equipment e.g. a wheelchair.



The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

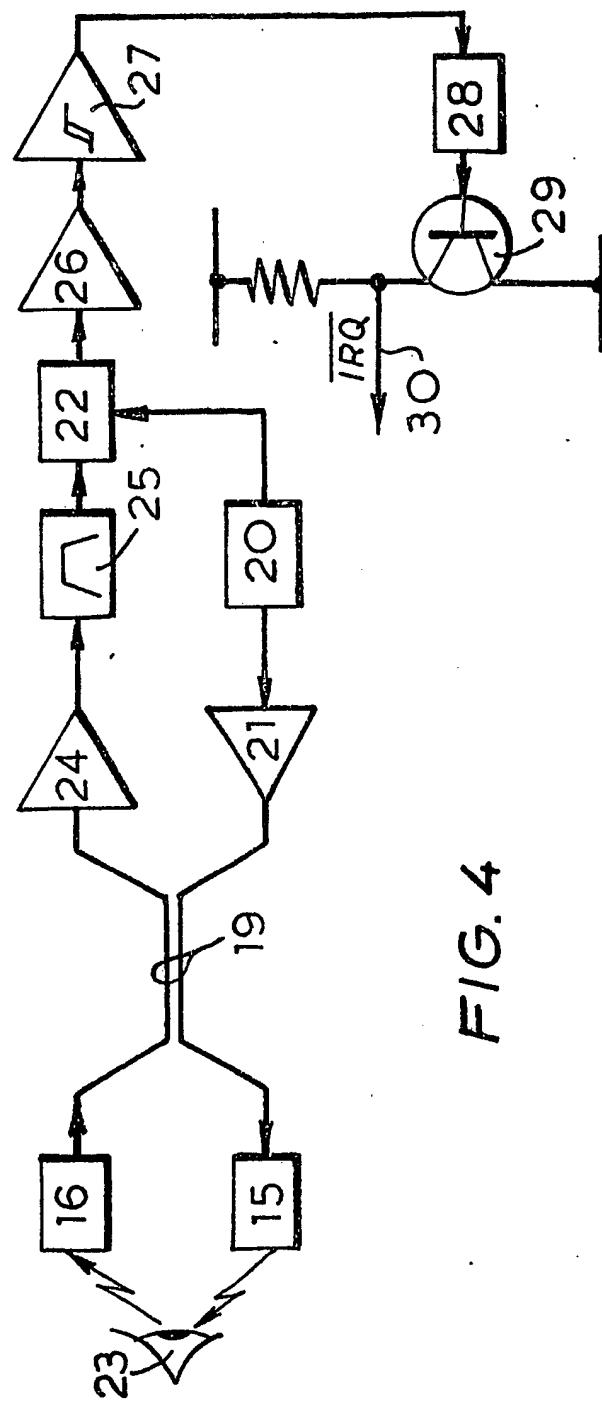
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SPECIFICATION**Control apparatus and methods
for the handicapped**

5 This invention relates to control apparatus suitable for use by severely physically handicapped people—for example quadriplegic athetoids—as well as to methods of control of 10 at least one function by such people.

People suffering from athetosis very often have considerable difficulty operating even simple equipment, in view of the loss of direct control of the movement of their limbs or 15 extremities. In the case of severe athetosis, communication with others can become extremely difficult because the vocal powers also may not be controllable, and this can lead to acute frustration because quite often the mental faculties remain relatively unimpaired, notwithstanding the physical handicap.

In an attempt to alleviate the problems of severely handicapped persons, such as quadriplegic athetoids, there have been developed 25 various devices adapted to respond to what limited physical control the person can muster. For example, equipment is known which can respond to gross movement of limbs whilst ignoring rhythmic lesser movements, the equipment being suitably coupled to a function to be controlled. Also known is equipment which can be connected to the head of a handicapped person and which is capable of responding to head movement, for 30 35 quite often control of head movements can be maintained even if there is no control of limb movements.

The above proposals are not suitable for use with the most severely physically handicapped, but there is known for such cases apparatus having a mouthpiece through which a person may suck or blow, the apparatus responding to detected changes in pressure. This apparatus has met with some measure of 40 45 success because even severely physically handicapped persons can usually manage to control the respiratory functions, but unfortunately the apparatus is expensive to manufacture, maintain and operate. Moreover, the bulk and complexity of the apparatus limits 50 the number of functions which can be controlled, and the speed of operation is very slow, restricted by the rate at which the person can control his sucking or blowing actions. The speed becomes important for 55 example in the case of a person trying to control a typewriter to express himself, where the person does not have vocal powers.

Observations of quadriplegic athetoids have 60 shown that, in addition to the control of the respiratory functions, there is almost invariably largely unimpaired control of the eyes, and this invention stems from the realisation that such a handicapped person may be able 65 to use his eyes to control other functions,

such as operating a typewriter or even a wheelchair.

Accordingly, this invention provides control apparatus for a physically handicapped person, comprising a frame for wearing in the manner of a pair of spectacles, a radiation transmitter mounted on the frame so as to direct radiation generally towards one eye of a user wearing the frame, a radiation receiver 70 75 also mounted on the frame and adapted to produce an electrical output on receiving radiation originating from the transmitter and reflected by the eye of a user, and electric circuit means arranged to respond to an output from the receiver and to produce a corresponding control signal.

In this invention, use is made of the relative reflective qualities of the parts of the eye—that is, the eyeball and the eyelid. When the 80 eyelid is closed, radiation directed at the eye is scattered by the eyelid, as compared with the characteristics of the eyeball. Though it may be possible suitably to position the transmitter and receiver so that the receiver normally receives radiation reflected from the eyeball when the eye is open, there being a fall in received level on closing the eyelid, it is however greatly preferred for the relative position of the transmitter and receiver to be such 85 90 95 that when the eye is open, only a small amount of radiation is received (because of the directional reflectivity and absorption characteristics of the eyeball), whereas when the eyelid is closed a relatively large amount of radiation is received due to the scattering effect of the eyelid directing some radiation back to the receiver. The electronic circuit means can then respond to this change in received radiation levels, to produce the control signal.

100 105 The transmitter advantageously radiates electromagnetic waves, preferably in the visible waveband, and to minimise any risk of damage to the user's eyes, only relatively low light levels should be employed. For example, 110 a light-emitting diode producing light in the red region has been found to be suitable. However, other wavelengths than visible light could be employed, or possibly even other forms of radiation—such as ultrasonic radiation. In order to eliminate the effect of ambient radiation of the same type as that transmitted to the eye, it is preferred to modulate the transmitted radiation at some frequency, the electronic circuit means ignoring outputs 115 120 125 from the receiver other than those correspondingly modulated. For example, in the case of a light-emitting diode being used as a transmitter, the current supplied thereto may be modulated at a relatively high frequency (for instance in the r.f. band), the output from the receiver being fed to a phase comparator also receiving the modulated waveform fed to the light-emitting diode. Then, only if the modulating waveform and the receiver output are in 130 phase would the circuit means produce a

control signal.

The receiver is advantageously in the form of a phototransistor when the transmitter is a light-emitting diode, in order to give a high sensitivity coupled with a good frequency response to detect the modulated transmitted light. Conveniently, the photo-transistor output is amplified and fed through a band pass filter before being passed to the phase com-

10 parator.

In order that a deliberate eyelid closure can be discriminated from a natural blink, the electronic circuit means preferably includes a delay circuit having a time constant slightly

15 greater than the longest normal blink time. Then, before the control signal is yielded, the relevant eyelid must remain closed for longer than the time constant of the delay circuit.

20 The control signal could be used to cause operation of a wide variety of equipment requiring a simple on/off control, but in order to increase the usefulness of the apparatus of this invention, it is greatly preferred for means to be provided which cyclically indicates one 25 of a number of functions, and which causes the indicated function to operate if a control signal is at that time yielded. For example, in the case of a powered wheelchair, such means could indicate on a display cyclically 30 and in sequence the functions of forwards, left, right, stop and reverse, the means causing the wheelchair to perform the required function upon the user closing his eyes when the intended function is displayed.

35 The most preferred form of the apparatus of this invention includes a computer and visual display unit (v.d.u.) adapted to respond to the control signal of the electronic circuit means. For example, to assist communication by a 40 quadriplegic athetoid, the computer may display in sequence on the v.d.u. the letters of the alphabet followed by the numbers 0 to 9; when the user sees a required character he closes his eyes thus producing the control 45 signal. The computer program may then respond to the generation of such a signal, to write the required character at the next available position in a line of such characters being built up in this way for example at the lower 50 part of the v.d.u.; when a whole line has been built up in this way, it could automatically be transferred to a hard copy printer also connected to the computer.

The characters are preferably displayed one- 55 at-a-time, at a size convenient for the person using the apparatus. However, the program could cause a whole character set to be written on the v.d.u., and then cause a cursor to indicate the characters in sequence, the operation otherwise being the same. Also, the program may be arranged to display—for example at pre-set intervals—a set of other functions, any of which could be selected in the same manner. Such functions could include 60 65 control of heating or ventilation, calling for

assistance or food, and so on. Yet another possibility would be for the program to recognise certain pre-defined reserved words which, when built up, would cause the computer to 70 perform a required function associated with that word. Clearly, in view of the great flexibility of a computer program, there is a very large number of other possibilities.

According to another aspect of this invention, there is provided a method of controlling a function by a handicapped person, comprising directing radiation towards the eye of the person, receiving radiation reflected from the eye both when the eye is open and is closed, 80 detecting the change in level of received radiation when the eye is closed, and producing a control signal in response to a detected change in received radiation levels which signal controls said function.

85 Preferably, the radiation directed towards the eye is visible light which advantageously is modulated at a predetermined frequency. Then, effects of ambient light can be eliminated by ignoring received radiation other 90 than correspondingly-modulated light.

In a most preferred method of this invention, a computer is caused by means of an associated program to indicate a succession of characters on a v.d.u. at a rate slower than 95 the response time of the user, and on receiving the control signal the computer causes the character for the time being indicated to be stored for further processing. The program may for instance cause that character to be 100 added at the next space of a line of such characters being built up on the v.d.u., and moreover may cause that line to be printed on a printer connected to the computer, when the line is complete.

105 By way of example only, one specific embodiment of apparatus of this invention will now be described in detail, reference being made to the accompanying drawings, in which:—

110 *Figure 1* is a diagrammatic view of that part of the apparatus worn by a user;

Figure 2 is a rear view of that part shown in *Fig. 1*;

Figure 3 is a plan view of that part shown 115 in *Figs. 1 and 2*; and

Figure 4 is a block diagram of a simple electronic circuit suitable for use with the part shown in *Fig. 1*, to produce a control signal.

The following description is of a specific 120 embodiment of this invention intended for use by severely physically handicapped people, such as those suffering from quadriplegic athetosis, who cannot exercise proper control of their limbs, extremities or voice, but who 125 can nevertheless still control their eye movements including the eyelid action.

Referring initially to *Figs. 1 to 3*, it can be seen that the part of apparatus worn by the handicapped person essentially is in the form 130 of a frame 10 of a pair of spectacles, which

may or may not be fitted with lenses, as appropriate. The frame 10 preferably is of the so-called 'sport' variety, in which the side bars 11 thereof have extended portions 12 which 5 curl round behind the ears of a user, so as more securely to hold the frame in the required position. In this way, the frame is less likely to be dislodged despite any involuntary movements of the user's head. The frame 10 could instead be of a known form intended for children's spectacles, having elastic attached thereto and which may pass around the head of the user, more securely to hold the frame in place.

15 Mounted on the upper member 13 of the frame 10 above one lens is a block 14 which carries a light-emitting diode 15 and a phototransistor 16, having optical axes 17 and 18 respectively. The diode 15, when energised, 20 thus will direct light generally towards the eye of a user, whilst the phototransistor 16 will receive light reflected from the eye. Conductors 19 are led from the block 14 along the frame and a side bar to a point adjacent the 25 free end of a side bar, whereat the conductors are secured to the side bar to prevent damage; from there the conductors trail to a connector (not shown) suitable for connection to an electric circuit (Fig. 4). Within the block 30 14, the conductors are appropriately connected to the light-emitting diode 15 and phototransistor 16.

The electronic circuit for use with the frame 10 is shown in Fig. 4, and comprises an 35 oscillator 20 feeding an amplifier 21 and a phase comparator 22. The amplifier 21 drives the light-emitting diode 15, such that the light generated thereby is modulated at the frequency of the oscillator 20, which typically is 40 in the r.f. band. The phototransistor 16 receives light reflected from the eye 23 of a user, and the phototransistor output is amplified by amplifier 24 and passed through a band-pass filter 25 to the phase comparator 45 22. An output from the phase comparator 22 only occurs when the output from the phototransistor is modulated at the same frequency and is in phase with the signal energising the light-emitting diode: this serves to eliminate 50 the effects of ambient light falling on the phototransistor 16.

The output from the phase comparator is 55 amplified by amplifier 26, the output driving a Schmitt trigger 27 which serves to ensure that drift of the amplifier 26 does not cause spurious operation. A delay circuit 28 delays an output pulse from the trigger 27, the delay period being set to be longer than the duration of a natural blink but shorter than the 60 duration of a deliberate eye closure. The delay circuit output drives a transistor 29, which produces a control signal on line 30, suitable for controlling a desired function. For example, in the preferred case in which the apparatus has been coupled to a computer, as

described hereinbefore, the control signal may take the form of an interrupt request IRQ, to cause the computer to perform some pre-programmed routine.

70 In use, the apparatus described above preferably has the control signal line 30 connected to a computer having a visual display unit and a program arranged to cause the computer cyclically to indicate the characters, 75 one at a time, of a displayed set. Then, on an interrupt request being received (the IRQ signal), the program causes the character instantaneously being indicated to be loaded at the next available space of a line of such characters being built up on the v.d.u. In this way, and by including in the character set special characters such as punctuation and reserved characters to cause a built-up line to be printed, complete sentences, paragraphs and 80 so on can be generated and produced in a hard copy.

The user simply has to wear the frame 10 having if required suitable lenses fitted thereto, and deliberately close his eyes on the 90 required character of the set being indicated. Conveniently, the characters are displayed at an appropriate size, one at a time, and the user then merely has to close his eyes briefly on seeing the required character. The speed 95 of character change should of course be made no faster than the user can follow, and this may vary from case to case.

It will be appreciated that in view of the directional reflective characteristics of the eye 100 when open, very little light from the light-emitting diode 15 will be reflected back to the phototransistor 16 so long as the eye remains open. However, on the user closing his eye on seeing the required character, the eyelid, 105 though less reflective than some parts of the eyeball, scatters light falling thereon and consequently a greater quantity of light is received by the phototransistor whilst the eyelid closes the eye.

110 Effects of ambient light are filtered out by modulating the transmitted light and comparing received light with the modulating signal. Moreover, involuntary blinking is ignored, by virtue of the delay circuit 28. Thus, a fast and 115 reliable means of communication may be achieved for even the most severely physically handicapped persons, and additionally the apparatus may easily be adapted to control a wide variety of functions besides the computer-controlled character-processing arrangement described above.

CLAIMS

1. Control apparatus for a physically-handicapped person, comprising a frame for wearing in the manner of a pair of spectacles, a radiation transmitter mounted on the frame so as to direct radiation generally towards one eye of a user wearing the frame, a radiation receiver also mounted on the frame and

125

adapted to produce an electrical output on receiving radiation originating from the transmitter and reflected by the eye of a user, and electric circuit means arranged to respond to 5 an output from the receiver and to produce a corresponding control signal.

2. Control apparatus according to claim 1, wherein the electric circuit means is arranged to respond to a change in received radiation 10 levels to produce the control signal, comparing the received radiation levels with the user's eyelid open and closed, respectively.

3. Control apparatus according to claim 2, wherein the electric circuit means is arranged 15 to produce the control signal when the received radiation level increases suddenly, corresponding to the user closing his eyelid.

4. Control apparatus according to any of the preceding claims, wherein the transmitter 20 radiates electromagnetic waves in the visible waveband.

5. Control apparatus according to claim 4, wherein the transmitter comprises a light-emitting diode having a transmission characteristic in the red region.

6. Control apparatus according to any of the preceding claims, wherein means are provided to modulate the transmitted radiation at a predetermined frequency, and the electronic 30 circuit means is arranged to ignore outputs from the receiver other than one which is correspondingly modulated.

7. Control apparatus according to claim 6, wherein the modulating means is arranged to 35 modulate current supplied to the transmitter and a phase comparator is provided to operate both on the output from the receiver and also on the modulated waveform fed to the transmitter, the production of the control signal 40 depending upon the output from the phase comparator.

8. Control apparatus according to any of the preceding claims, wherein the receiver is a phototransistor.

45 9. Control apparatus according to claim 8, wherein an amplifier and a band pass filter are provided to operate on the output from the phototransistor.

10. Control apparatus according to any of 50 the preceding claims, wherein the electric circuit means includes a delay circuit having a time contact slightly greater than the longest typical blink time of a user.

11. Control apparatus according to any of 55 the preceding claims, wherein means are provided which cyclically indicate one of a number of functions, and which cause the indicated function to be operated if a control signal is at that time yielded.

60 12. Apparatus according to claim 11, wherein there is provided a computer which drives a visual display unit and which is adapted to respond to the control signal produced by the electric circuit means.

65 13. A method of producing a control sig-

nal by a handicapped person, comprising directing radiation towards the eye of the person, receiving radiation reflected from the eye both when the eye is open and is closed,

70 detecting the change in level of received radiation when the eye is closed, and producing a control signal in response to a detected change in received radiation levels which signal controls said function.

75 14. A method according to claim 13, in which the radiation directed towards the eye is visible light.

15. A method according to claim 14, in which the visible light is modulated at a 80 predetermined frequency.

16. A method according to claim 15, in which the received radiation is fed to a phase comparator for comparison with the modulation of the directed radiation, and the control 85 signal is produced depending upon the comparison.

17. A method according to any of claims 13 to 16, in which the received radiation is fed through a delay circuit having a time 90 constant slightly greater than the longest typical blink time of the person so as to allow discrimination between a natural blink and a deliberate eyelid closure for producing a control signal.

95 18. A method according to any of claims 13 to 17, in which a computer is caused by means of an associated program to indicate a succession of characters on a visual display unit at a rate slower than the response time of 100 the handicapped person, and the control signal is supplied to the computer to cause the computer to store the character for the time being indicated for further processing.

19. Control apparatus substantially as 105 hereinbefore described with reference to and as illustrated in the accompanying drawings.

20. A method of producing a control signal substantially as hereinbefore described with reference to the accompanying drawings.

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